Towards an Operational Forecast Model Suite for Compound Inundation due to Flash Floods and Storm Tides in Coastal Areas with Non-Perennial Rivers

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Abstract:
Coastal zones with non-perennial river systems face heightened flood risk due to the compounding effects of intense pluvial events, fluvial overflows, and storm surges/tides, especially under changing climatic conditions. This study presents an integrated modeling framework for the operational forecasting of compound coastal inundation, applied in the Northern Thermaikos Gulf and surrounding lowland zones, including the Anthemountas River basin. The proposed suite combines advanced hydrodynamic models for storm surge (HiReSS), a high-resolution coastal inundation simulation (CoastFLOOD), and rain-on-grid hydraulic modeling using HEC-RAS 2D with direct precipitation input.

The combined storm surge and astronomical tide component is captured by feeding atmospheric forcing (WRF-ARW) into the HiReSS model to simulate sea level anomalies under cyclonic systems. Coastal flood extents are simulated with the CoastFLOOD model and validated using Sentinel-2 NDWI imagery and tide gauge data. In parallel, non-perennial river flash floods are modeled via direct rainfall methods within HEC-RAS 2D, accounting for topography, soil conditions, and land use to resolve local hydrological responses without requiring upstream hydrographs.

To support operational readiness, the new model suite is integrated within the Wave4Us forecast system, which provides 3-day predictions under real-time met-ocean conditions daily. This multi-layer approach enhances early-warning capabilities for civil protection, particularly in urbanized and touristic littoral zones with ephemeral streamflow networks.

The results underscore the importance of high-resolution (dx=2-5m), coupled inland-coastal modeling systems to address compound flooding scenarios. The synergy between atmospheric, hydrological, hydraulic, and oceanographic modules enables dynamic simulations of spatially and temporally variable compounds and/or flash flood drivers. This approach offers a promising pathway toward a robust operational forecast tool for climate-resilient flood risk management in vulnerable Mediterranean coastal environments with high exposure of critical elements (infrastructure, buildings, businesses, natural settings, and public spaces) to inundation.

Keywords: coastal zone; non-perennial river; compound flooding; flash flood; operational forecast system; HEC-RAS 2D; CoastFLOOD